**Quick Guide**

# Dendritic Spines

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***What are they?*** Dendritic spines are small protrusions that emerge from the dendrites of neurons (Figure 1). Most excitatory synapses in the brain are found on spine heads. Typically, a spine consists of a bulbous head, volume 0.001–1 $\mu m^3$, at the end of a thin spine neck, diameter around 0.1 $\mu m$. A 100 $\mu m$ length dendrite can contain several hundred spines. The human cerebral cortex is thought to contain in the order of $10^{14}$ spines!

***What's in a spine?*** A great deal considering their small size. All spines contain a postsynaptic density, an electron-dense thickening where the presynaptic axon contacts the spine. The postsynaptic density is made up of neurotransmitter receptors, ion channels, scaffolding proteins and signaling molecules. Some spines may also contain smooth endoplasmic reticulum, which can elaborate into stacks called the spine apparatus. Polyribosomes are frequently present in the spines, and are hypothesized to be sites of local protein synthesis. An actin-based cytoskeleton provides the means for structural organization as spines mostly lack microtubules and intermediate filaments.

***Do all spines look alike?*** No! Spines come in many shapes and sizes: there are those which are short and thick with no neck, 'stubby'; some that are thin with a small head, 'thin'; others with a large head and a constricted neck, 'mushroom'; and there are even some spines which branch into two heads that share the same neck, 'branched'. Spines are not to be confused with filopodia, which are longer and thinner, usually transient, and occur most frequently during development.

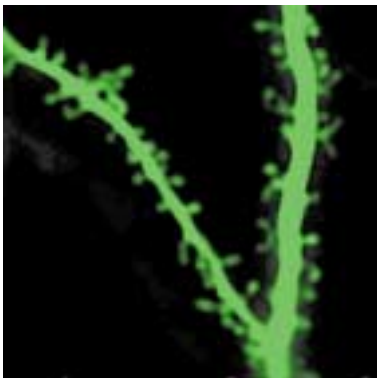

Figure 1. Two-photon image of dendrites and spines from a hippocampal pyramidal neuron expressing green fluorescent protein (EGFP).
Cultured hippocampal slices were prepared from P7 rats, transfected with EGFP using particle-mediated gene transfer, and imaged after one week in culture.

***Can spines change shape?*** Yes! Recent advances in imaging technology have permitted time-lapse observation of spine morphology in living neurons, using fluorescent dyes in combination with confocal or two-photon laser scanning microscopy. Over timescales of seconds, spines continuously undergo small changes in shape, powered by dynamic actin filaments. On timescales of minutes to hours spines can change their shape dramatically or even appear or disappear. Interestingly, new spines can be generated in response to synaptic stimulation that also results in strengthening of synapses. These morphological changes could underlie some of the changes in synaptic strength induced by neural activity.

***What are spines for?*** Nobody really knows. Some proposed functions for spines include increasing the packing density of synapses, the prevention of excitotoxicity, and modulation of synaptic efficacy through effects of changes in spine neck morphology on synaptic currents. But probably the most popular hypothesis is that, due to their morphology — large head connected by very thin neck — spines act to compartmentalize molecules to individual synapses. In this way, activation of one synapse could result in selective strengthening of that synapse, without influencing neighboring synapses. Such synapse specificity is an important requirement for models of learning and memory. Recent studies support this hypothesis, showing that spines can compartmentalize the important intracellular messenger calcium.

***Can having more spines make us smarter?*** Probably it's not so simple as that, but there are some correlative data. Animals exposed to an enriched environment show increased spine densities, and at the same time these animals are better at solving spatial memory tasks. Conversely, many neurological diseases resulting in mental retardation have been associated with spine loss or spine morphology changes, but whether these changes are causative or a consequence of the disease is not yet clear.

### *Where can I find out more?*

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